SOME ASPECTS OF FISH MYOLOGY

Dissertation submitted for the degree
of
MASTER OF PHILOSOPHY
to
The Aligarh Muslim University
Aligarh

By
SALEEM MUSTAFA
M. Sc. (Alig.)

DEPARTMENT OF ZOOLOGY
ALIGARH MUSLIM UNIVERSITY,
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C O N T E N T S

GENERAL INTRODUCTION

Despite the very anatomical location and constancy, studies on the organisation of axial muscles of the trunk and tail regions of fish have been relatively few, notable being those of Alexander (1969), Bishop and Odense (1967), Eaton (1951), Franzini-Armstrong and Porter (1964a, b), Ganguly and Nag (1964), Inke and Sitka (1965), Jarman (1961), Kilarsky (1965a, b), Nag (1967), Nursall (1963), Partmann (1966), Peters and Mackay (1961), VanDer Stelt (1969) and Watson (1959), as compared to the considerable literature on the morphology of muscles of other body locations (Baumgarton, 1965; Battacharya, 1962; Chabanand, 1950; Couteaux and Laurent, 1957; Datta, 1964; Dubale, 1952; Dubale and Shah, 1959; Gottenhos, 1956; Gunther and Deckert, 1955; Holstvoogd, 1965; LeDanois, 1966; Munshi, 1960; Nelson, 1967; Nishihara, 1967; Oliva, 1965; Reger, 1961; Saxena, 1960; Spannhof, 1959; Thiele, 1965 and Thomas, 1956). Similarly, although considerable work has been done in the past on the growth of various fish species, including on Indian forms (Antony Raja, 1970; Balan, 1968; Bhatt, 1969, 1970; Jhingran, 1959, 1972; Kamal, 1969; Natarajan and Jhingran, 1963; Pantulu, 1963; Qasim and Bhatt, 1966; Raj, 1951; Rangarajan, 1973; Seshappa and Bhimachar, 1954), information on the growth of fish myotomes remains unsatisfactory. Excepting for the classical work of Love (1958, 1970) on the Atlantic cod (*Gadus morhua*), nothing seems to have appeared on the subject in detail. An attempt has, therefore, been made by the present author to work out the gross morphology of the axial muscles of the trunk and tail regions and, the problem of growth of the myotomes of the common pond murrel, *Ophicephalus punctatus* Bloch. The work presented here in the form of a dissertation is perhaps the first detailed study of its kind on the quantitative myology of an Indian teleost.

In a metamerically defined animal like fish, it was thought necessary to analyse the pattern of arrangement of myotomes and myosepta which, if traced in detail, is rather complex. As Ganguly and Nag (1964) put it: "The problem of the nature and arrangement of the myomeric musculature is a most vexatious one".

A study of the general organisation of the myotomes formed the basis of deriving some generalisations as to the classification of the myotomes into architectural type, their regional differentiation and relationship with the axial skeleton of the fish.

The present work is largely a quantitative approach which can lead to an explanation of growth in its general course as well as in its specific peculiarities, to quantitative expressions, permitting calculations of various relationships, as they exist, between the dimensions of the different myotomes, as well as those between the myotomes and the body length of the fish.

For the elucidation of interspecific differences in the relationship between the thickness of myotomes and body length of the fish, a similar investigation was conducted on *Ophicephalus striatus* Bloch.

Besides evaluating the logarithmic relationship between different myotomes, regression equations establishing an interesting relationship between the myotome thickness and body length of the fish have been worked out and the latter also expressed by 'myosomatic' ratios and indices. Using the regression methods, an attempt has also been made to establish the relationship between the lengths of the epaxial and hypaxial portions of the myotome and between these and the body length of the fish.

The quantitative analysis of growth of the myotomes, in the present study, consists of fitting straightline logarithmic plots between myotome thickness and body length of the fish, to regression formulae, besides establishing the age-specific growth characteristics of the individual myotome.

The significance of quantitative analysis of growth seems to have been realised as early as 1932 when Huxley suggested "... without the quantitative expression, we should be largely theorizing in the air". Indeed, modern research is no more haphazard groping but an orderly production of knowledge by subjecting the measurable entities to quantitative statistical analysis (Rounsefell and Everhart, 1953).

The present investigation, it is hoped, would give a dynamic turn to fish myology as a subject of great academic importance and fascination. The study assumes more significance since it provides a much awaited myological account of one of the commonest freshwater teleosts which has a wide geographical distribution in the Asian continent.

PROCEDURE AND METHODOLOGY

The fishes examined during the course of the present investigations were obtained live from the local fish market and transferred to the laboratory aquaria. Inquiries from the fishermen suggested that these were caught from the river Kali and some larger ponds of Aligarh (lat. $27^{0}34'30''$ N, long. $78^{0}4'26''$ E).

At the time of investigation each specimen was taken out, asphyxiated to death and examined in various ways.

Removal of the skin and measurements of the thickness of myotomes

The fishes were skinned from the point of severance of the head to the tail. Care was taken to avoid any injury to the muscles. The 4th and 21st myotomes (as counted from the anterior region) were selected for measurements of the thickness (distance between two adjacent myocommata). The measurements were carried out on the 'skin' side of the fillet, above the lateral septum.

Filleting

The fillets were removed by a sharp knife inserted in the region of caudal peduncle, deep upto the vertebral column and pulled carefully towards the anterior side, as far as the commencement of the head.

Sectioning

The region of the body of greater girth, adjacent to the dorsal fin, was selected and sectioned exactly at right angles.

Measurements of the epaxial and hypaxial portions, median skeletogenous and lateral septa

In the cross-sections, thus cut, various measurements of the components of the myotome were made. The epaxial portion was measured all along the edge of the cut section, from the region of the dorsal septum to the lateral septum, while the hypaxial portion was measured in the similar way, all along the edge of the cut section, from the lateral septum to the linea alba.

The distance the lateral septum traverses in passing inward was measured from the surface to the median skeletogenous septum.

The dorsal portion of the median skeletogenous septum was measured from the lower extremity of the vertebral centrum straightup at right angles upto the region of the commencement of the muscles of the dorsal fin ray.

Methods of calculation

I. Logarithmic relationship:

For the establishment of logarithmic relationship between the dimensions of two structures the following regression equation was used:

$$\log x = a + b \log y$$

Where, x and y were the dimensions of the two structures (mm); and a and b were constants, determined by the method of least squares.

II. The standard deviation (SD); coefficient of variability (Cv); coefficient of difference (CD); variance (V); variance ratio (VR); standard errors of mean (SEm), difference (SEd), standard deviation (SEsd), and coefficient of variability (SEcv); correlation coefficient (r); standard error of correlation coefficient (SEr); 'F', 'z' values, together with the statistical significance, were computed by the methods given by Snedecor (1955).

III. Absolute growth:

The absolute growth of the myotomes, in thickness, was estimated as the mean thickness at each age. This has been plotted as the regression of myotome-thickness on age.

The rate of absolute growth in the thickness of the myotomes has been described as yearly gains in myotome thickness per year.

IV. Relative growth:

The relative growth in the thickness of the myotome was calculated as an increase in growth in each time interval as a percentage of the growth at the beginning of the time interval and this was estimated using the following formula:

$$Rg = \frac{Gm}{Gb} \times 100$$

Where, Rg = relative growth, Gm = gain in myotome thickness during a year, and Gb = thickness of myotome at the beginning of the year.

V. Myosomatic index:

The myosomatic index (MSI) was determined as the myotome thickness as a percentage of the total body length using the following formula:

$$MSI = \frac{Mt}{Bl} \times 100$$

Where, MSI = myosomatic index, Mt = thickness of myotome, and Bl = total body length of the fish (mm).

VI. Myosomatic ratio:

The myosomatic ratio (MSR) was determined as the ratio between the myotome thickness and the total body length of the fish using the following equation:

$$MSR = \frac{Mt}{Bl}$$

Where, MSR = myosomatic ratio, Mt = thickness of myotome, and Bl = body length of the fish.

CHAPTER - I

SOME ASPECTS OF THE ANATOMY OF AXIAL MUSCULATURE OF THE POND MURREL, *OPHICEPHALUS PUNCTATUS* BLOCH.

INTRODUCTION

Information on the details of the organisation and differentiation of lateral muscles of the trunk and tail regions, and the statistical evaluation of the various relationships, as they exist, between the dimensions of different myomeric components and the body length of the fish, especially of the Indian freshwater teleosts, seems lacking. The present chapter describes the gross morphology of a common pond murrel, *Ophicephalus punctatus* Bloch. Some aspects of the quantitative myology of this species have been dealt in detail.

MATERIALS AND METHODS

Ophicephalus punctatus of the size-range 120 to 240 mm were selected for these investigations.

The methods used for the measurements of various myomeric components and for stablishing the estatistical relationships between different myomeric components and with the body length of the fish were the same as described under 'Procedure and Methodology' (pages 5-7).

Fig. 1 Fillet of _O. punctatus_

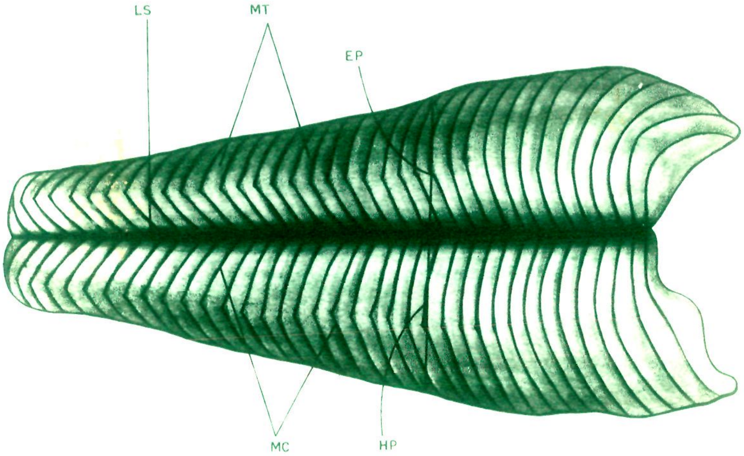
EP, epaxial portion,

HP, hypaxial portion,

LS, lateral septum,

MT, myotomes,

MC, myocommata.



LS
MT
EP
MC
HP

RESULTS AND DISCUSSION

The longitudinal somatic muscles of the trunk and tail regions were found to constitute the axial musculature of *O. punctatus*. The axial muscles showed perfect metamerism, being composed of a series of segments, the myotomes, which were separated from one another by myocommata (Fig. 1). The myocommata seemed to extend inward, getting attached to the vertebral column.

Architecturally, the somatic musculature of the trunk and tail of *O. punctatus* was typically of 'piscine' type. Each such piscine myotome of the fish was > -shaped, with markedly sharp flexures. The flexures of the myotomes formed cones with their open ends directing backward and the apices directing forward. The open ends and the apices of the flexures, on the other hand, exhibited a reverse arrangement.

The myotomes were differentiated into dorsal epaxial and ventral hypaxial portions. This division of the myotomes was brought about by the presence of a lateral septum, running along the trunk and tail regions, at the level of the lateral line (Fig. 1).

The epaxial portions of each of the myotomes of right and left sides were separated dorsally by a dorsal septum while the hypaxial portions were separated ventrally by another septum, the linea alba.

The sizes of the epaxial and hypaxial portions of each of the myotomes, as measured along the outer surface, from dorsal septum to the lateral septum and from the lateral septum to the linea alba, respectively, were found to differ markedly in *O. punctatus* (Table I).

The differences seemed to be due to the location of the lateral septum. Since the lateral septum was not situated exactly equidistant from the dorsal septum and the linea alba but was slightly more towards the dorsal septum, it rendered the two major muscle masses (epaxial and hypaxial) of unequal sizes.

In the fishes of the body lengths 120 mm, 170 mm, 220 mm and 248 mm the mean lengths of the epaxial portion at the region of the greater girth, adjacent to dorsal fin, were 12.26mm, 19.40 mm, 27.20 mm and 29.00 mm, respectively. The standard deviation for 4 degrees of freedom ranged from 0.089 to 0.771 in the different size-groups of fish. The variance and the coefficient of variability ranged from 0.007 to 0.594 and 0.725 to 3.030, respectively. The mean lengths of the corresponding hypaxial portions were 18.00 mm, 27.22 mm, 36.44 mm and 38.50 mm in the fishes of the different size-groups investigated (Table 1). The standard deviation for 4 degrees of freedom varied from 0.070 to 0.736. The variance ranged from 0.004 to 0.541, and the variability coefficient from 0.388 to 2.703.

The standard errors of difference (SEd) between the lengths of epaxial and hypaxial portions were calculated as 0.049, 0.420, 0.366 and 0.471, while the coefficients of difference (CD) as 36.100, 5.906, 10.819 and 6.367, in the fishes belonging to 120 mm, 170 mm, 220 mm and 248 mm size-groups respectively (Table II).

In the more anterior region of the fillet, the lateral septum was found to take a curve. This curve was convex towards the hypaxial

Fig. 2 Cross section of _O. punctatus_ through the region of greater girth, adjacent to dorsal fin.

EP, epaxial portion,

HP, hypaxial portion,

LS, lateral septum,

DLB(1), first dorsal longitudinal bundle,

DLB(2), second dorsal longitudinal bundle,

LLB, lateral longitudinal bundle,

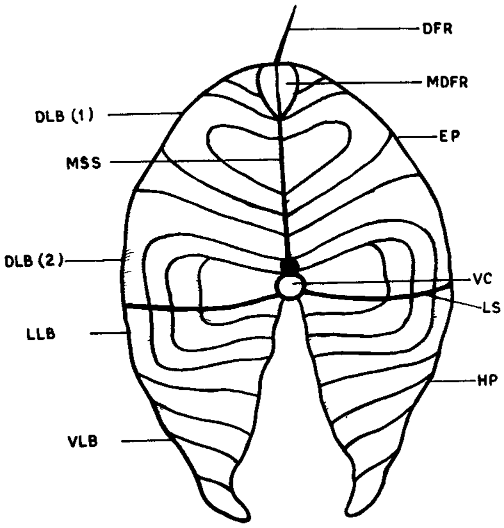
VLB, Ventral longitudinal bundle,

MDFR, musculature of dorsal fin ray,

DFR, dorsal fin ray,

VC, vertebral centrum,

MSS, median skeletogenous septum.



DFR
MDFR
DLB (1)
EP
MSS
DLB (2)
VC
LS
LLB
HP
VLB

region and was then found to lift up markedly towards the epaxial region, with the result the hypaxial region, at the point where the curve attained its maximum convexity, was rendered shorter than the region lying anterior to it, from where the lateral septum was lifted upwards. On the contrary, the condition was just the reverse for the epaxial region. The corresponding epaxial region, where the lateral septum reached its maximum concavity was of greater size then the region from where the lateral septum was lifted up.

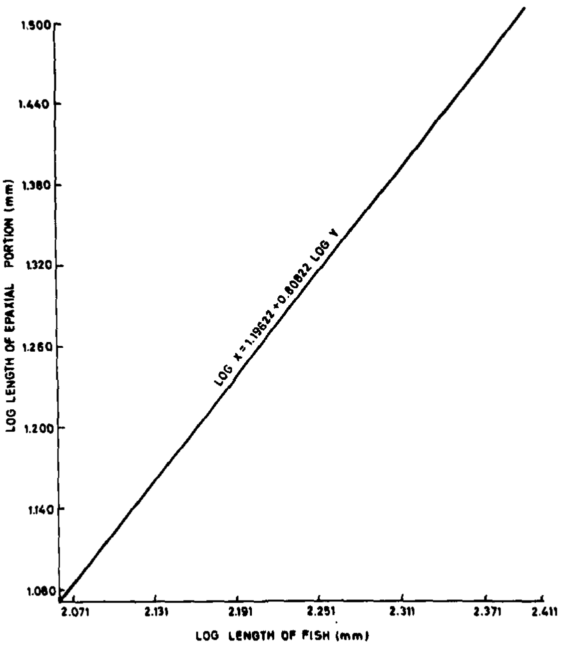
This disparity in the sizes was marked with respect to either the epaxial or the hypaxial regions and in no case, however, the hypaxial portion was shorter than the corresponding epaxial portion of the same myotome (Fig. 1).

The lateral septum was found to extend inward, meeting the centra of the vertebrae. The mean distance which it so traversed was 7.52 mm, 10.96 mm, 14.68 mm and 17.50 mm in the fishes of the size-groups 120 mm, 170 mm, 220 mm and 248 mm respectively (Table I). The standard deviation for 4 degrees of freedom varied from 0.083 to 0.886, the variance from 0.006 to 0.784, and the coefficient of variability from 1.103 to 5.062.

The muscle segments of the lateral musculature of either side were found to extend from below the skin deep into the body axis and became limited at the midline by a median skeletogenous septum (Fig. 2).

The lateral septum which separated the two major muscle masses of either side by its very location, and the median skeletogenous septum by

Fig. 3 Relationship between the length of epaxial portion and body length of *O. punctatus*.


LOG LENGTH OF EPAXIAL PORTION (mm)
1.500
1.440
1.380
1.320
1.260
1.200
1.140
1.080
LOG X = 1.19622 + 0.80822 LOG Y
2.071
2.131
2.191
2.251
2.311
2.371
2.411
LOG LENGTH OF FISH (mm)

its vertical position, resulted in the arrangement of the trunk and tail muscles into quadrants. The epaxial muscles were found to constitute the upper or dorsal quadrants while the hypaxial muscles constituted the lower or ventral quadrants.

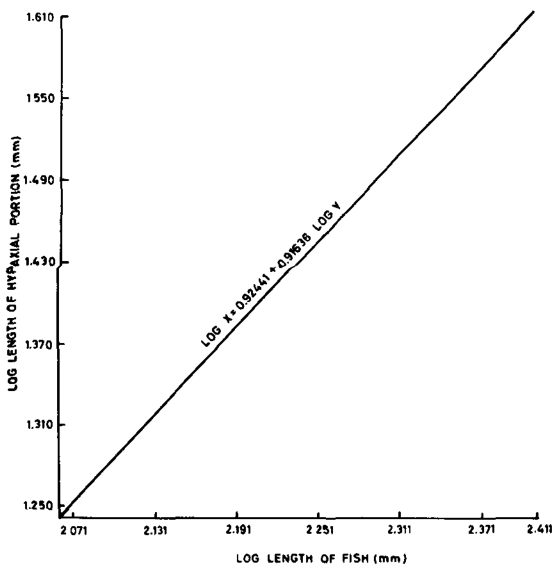
The epaxial portions of the myotomes of O. punctatus were composed of two dorsal longitudinal bundles while the hypaxial muscles were composed of a lateral and a ventral longitudinal bundles (Fig. 2).

It was observed that in extending inward, the myotomes and the myocommata did not meet the sagittal axis of the body at right angles but intercepted it at an angle which was more sharp in the region of the tail. This became evident when a needle was inserted at right angles to the segittal plane in a particular myotome of the tail region; the needle passed this myotome and entered the other myotome instead of going all the way into the same myotome, indicating that the myotomes did not extend at right angles to the segittal axis. A somewhat similar pattern of arrangement of the myotomes and myocommata has been reported by Love (1970) in the cod, Gadus morhua, where these were found not to run vertically from 'bone' side to 'skin' but taking a curve towards the tail end within the thickness of the fillet in a rather complex pattern.

The thickness of the myotomes and the lengths of the epaxial and hypaxial portions were found to be in correlation with the body length of the fish (Figs. 3, 4, 6 and 7).

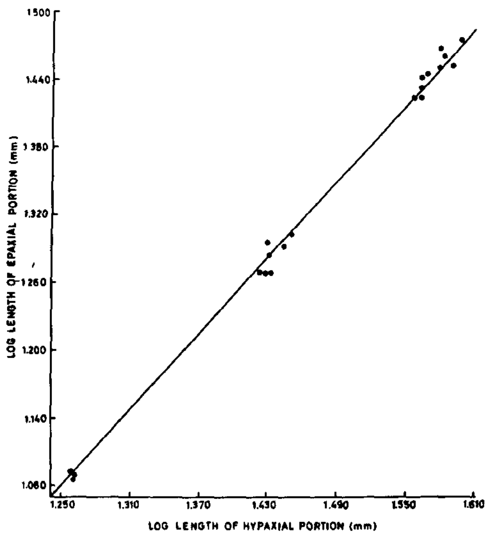
The relationship between the thickness of the myotomes and the

Fig. 1 Relationship between the length of hypaxial portion and body length of *O. punctatus*.



LOG LENGTH OF HYPAXIAL PORTION (mm)
1.610
1.550
1.490
1.430
1.370
1.310
1.250
LOG X = 0.92441 + 0.91636 LOG Y
2 071
2.131
2.191
2 251
2.311
2.371
2.411
LOG LENGTH OF FISH (mm)

Fig. 5 Hypaxial/epaxial length relationship in *O. punctatus*.


LOG LENGTH OF EPAXIAL PORTION (mm)
1.500
1.440
1.380
1.320
1.260
1.200
1.140
1.080
1.250
1.310
1.370
1.430
1.490
1.550
1.610
LOG LENGTH OF HYPAXIAL PORTION (mm)

the body length of *O. punctatus* has been discussed in a separate chapter (pages 16-19).

A direct correlation between the lengths of the epaxial and hypaxial portions with the body length of the fish (Tables III and IV), as worked out through regression methods of analyses, was expressed as:

$$\log x = 1.1962 + 0.8082 \log y$$

Where, x was the body length of the fish (mm), and y was the length of the epaxial portion (mm).

$$\log x = 0.9244 + 0.9163 \log y'$$

Where, x was the body length of the fish (mm), and y' was the length of the hypaxial portion (mm).

The logarithmic equation establishing the relationship between the lengths of the epaxial and hypaxial portions was worked out to be:

$$\log x = 0.2776 + 0.8964 \log y$$

Where, x was the length of the hypaxial portion (mm) and y was the length of the epaxial portion.

The above relationship between the hypaxial and epaxial portions has been graphically shown in Fig. 5.

The correlation coefficients between the body length and the length of the epaxial portion was found to be 0.9936, significant at 1% level ($P > 0.01$), $z = 2.8$, and that between the body length and the length of the hypaxial portion was 0.9930, significant at 1% level ($P > 0.01$), $z = 2.8$.

The intraspecific variations in the various relationships, as described above, have been computed in Tables III - XI.

SUMMARY

The lateral (axial) musclature of the trunk and tail regions of <u>O. punctatus</u> was found typically of 'piscine' type.

In extending inward, the myotomes and myocommata did not meet the sagittal axis at right angles.

The logarithms of the lengths of each of the epaxial and hypaxial portions of the myotomes maintained direct proportionality with the logarithm of the body length of the fish.

The statistical analysis of the intraspecific epaxial and hypaxial length relationship gave 0.2776 and 0.8964 regression constants. The correlation coefficient between the epaxial length and body length, and that between hypaxial length and body length were found to be 0.9936 and 0.9939, respectively.

CHAPTER - II

THE MYOTOME THICKNESS-BODYLENGTH RELATIONSHIP IN THE POND MURREL, *OPHICEPHALUS PUNCTATUS* BLOCH

INTRODUCTION

An interesting outcome of a series of investigations on the myology of the common pond murrel, *Ophicephalus punctatus* Bloch, was the establishment of relationships between the thickness of the 4th and 21st myotomes and their relationships with the body length of the fish. Besides the logarithmic transformation, these relationships were expressed by what the author proposes to call the 'myosomatic ratios' and 'mysomatic indices'. The statistical analyses of the intraspecific variations in these relationships have also been worked out.

MATERIALS AND METHODS

The methods used for the measurements of the thickness of the myotomes and for the statistical analyses were the same as described under 'Procedure and Methodology' (pages 5-7).

RESULTS AND DISCUSSION

The logarithms of myotome thickness and body length of *O. punctatus*

Fig. 6 Relationship between the thickness of 4th myotome and body length of *O. punctatus*.

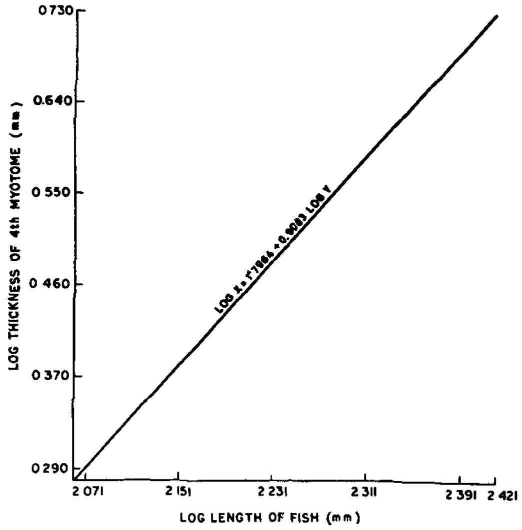

0 730
0.640
0 550
0 460
0 370
0 290
LOG THICKNESS OF 4th MYOTOME (mm)
LOG X = Ī7964 + 0.9083 LOG Y
2 071
2 151
2 231
2 311
2 391
2 421
LOG LENGTH OF FISH (mm)

Fig. 7 Relationship between the thickness of 21st myotome and body length of *O. punctatus*.

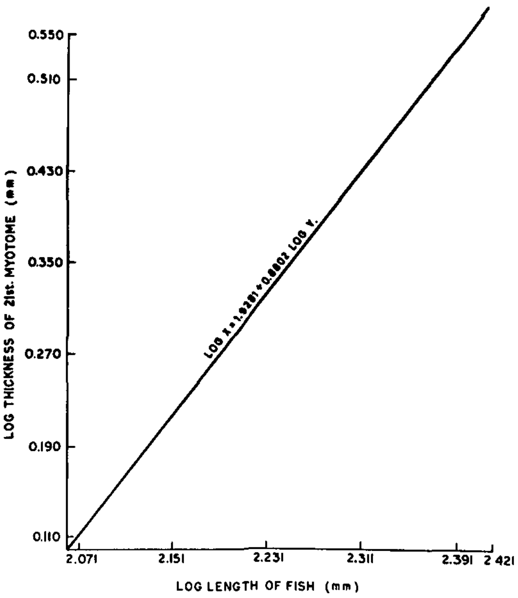
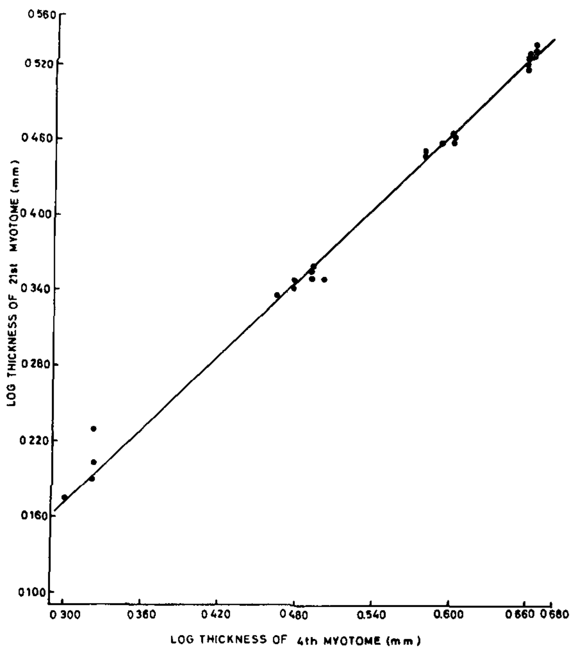

0.550
0.510
0.430
0.350
0.270
0.190
0.110
LOG THICKNESS OF 21st. MYOTOME (mm)
LOG X = 1.9281 + 0.8802 LOG Y.
2.071
2.151
2.231
2.311
2.391
2 421
LOG LENGTH OF FISH (mm)

Fig. 8 Relationship between the thickness of 4th and 21st myotomes of *O. punctatus*.


0.560
0.520
0.460
0.400
0.340
0.280
0.220
0.160
0.100
LOG THICKNESS OF 21st MYOTOME (mm)
0.300
0.360
0.420
0.480
0.540
0.600
0.660
0.680
LOG THICKNESS OF 4th MYOTOME (mm)

The correlation coefficient (r_2) for this relationship was calculated to be 0.9887 $\pm$ 0.0045, significant at 1% level (P 0.01), z 2.5.

The myosomatic ratio (MSR_{21}) ranged from 0.0125 to 0.0136. The SEm and the C_v were found to be 0.0002 and 3.8461, respectively (Table XI). The myosomatic index (MSI_{21}), however, varied from 1.250 to 1.366, with a SEm of 0.0232 and Cv of 3.5469 (Table XI).

The standard error of difference (SEd) and the coefficient of difference (Cd) between the two myosomatic ratios (MSR_4 and MSR_{21}) were found to be 0.0003 and 4.1666, respectively, while those for the two myosomatic indices (MSI_4 and MSI_{21}) being 0.0244 and 4.4056, respectively.

The inter-relationship between the thickness of the 4th and 21st myotomes was expressed by the equation:

$$\text{Log } x = 0.1432 + 0.9737 \log y$$

Where, x was the thickness of 4th myotome and y was the thickness of 21st myotome).

The straight line relationship has been shown in Fig. 8.

The correlation coefficient (r_3) for this relationship was found to be 0.9930 $\pm$ 0.0026, significant at 1% level (P $>$ 0.01), z = 2.8.

SUMMARY

A direct logarithmic proportionality was found to exist the thickness of the myotomes (4th and 21st), as also between the thickness of each of these myotomes and the body length of the murrel, *Ophicephalus punctatus* Bloch. The myotome thickness-body length relationship was expressed by the myosomatic ratios and myosomatic indices.

CHAPTER - III

THE GROWTH CHARACTERISTICS OF THE MYOTOMES OF THE POND MURREL, OPHICEPHALUS PUNCTATUS BLOCH.

INTRODUCTION

The establishment of myotome thickness-body length relationship in *Ophicephalus punctatus* Bloch. (see Chapter II) provided an opportunity to work out the pattern of growth of the myotomes, in thickness, in this species.

The present investigation introduces, perhaps for the first time, an account of growth of the myotomes of a freshwater teleost from a tropical environment and a correlation between the growth of the myotomes and that of the body length of the fish, besides establishing the range of intraspecific variations. The study also furnishes the differential growth rates of different myotomes, and the degree of constancy of the ratios of these growth rates. The investigation assumes significance since it establishes the general and specific peculiarities of the myotome growth in fish, information on which, hitherto, remained inadequate.

MATERIALS AND METHODS

Fishes of the size-range 120 mm to 240 mm, belonging to year-classes 0^+ to 3^+ were obtained from the local ponds of Aligarh. The recognition of the different age-groups was based on the scheme proposed by Qasim and Bhatt (1966). The myotome thickness, absolute and relative growths, the differential growth rates, together with their ratios and indices, and the range of intraspecific variations were assessed by the methods mentioned under 'Procedure and Methodology' (pages 5-8).

RESULTS AND DISCUSSION

The regularity with which the myotomes of O. punctatus were found to grow in thickness was accompanied by an increase in the body length of the fish.

In the fishes of 0^+ to 3^+ year-classes, belonging to 12 mm, 170 mm, 220 mm and 248 mm, the mean thickness attained by the 4th myotome were found to be 2.04 ± 0.020, 3.04 ± 0.020, 3.92 ± 0.095, 4.58 ± 0.006 and that attained by the 21st myotome were 1.50 ± 0.052, 2.24 ± 0.015, 2.89 ± 0.015, 3.39 ± 0.020, respectively (Table XI).

A corollary to the present finding was apparent in the earlier observations of Love (1958) on the north Atlantic cod (Gadus morhua) where a direct correlation between the width of the myotomes (as measured on the 'bone' side of the fillet) and body length of the fish was reported to exist. In an earlier chapter (pages 16-19), straightline relationships between the logarithms of the thickness of myotomes and body length of O. punctatus have already been discussed.

Fig. 9 Correlation between the growth of the 4th myotome and that of the body length of <u>O</u>. <u>punctatus</u>.

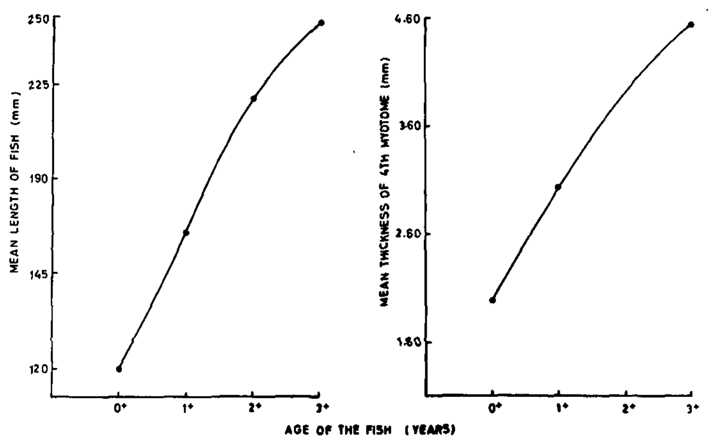

MEAN LENGTH OF FISH (mm)
250
225
190
145
120
0+
1+
2+
3+
MEAN THICKNESS OF 4TH MYOTOME (mm)
4.60
3.60
2.60
1.60
0+
1+
2+
3+
AGE OF THE FISH (YEARS)

Fig. 10 Differential growth characteristics of the myotomes of _O_. _punctatus_.

A, absolute growth of 4th myotome,

B, absolute growth of 21st myotome,

C, growth rate of 4th myotome,

D, growth rate of 21st myotome;

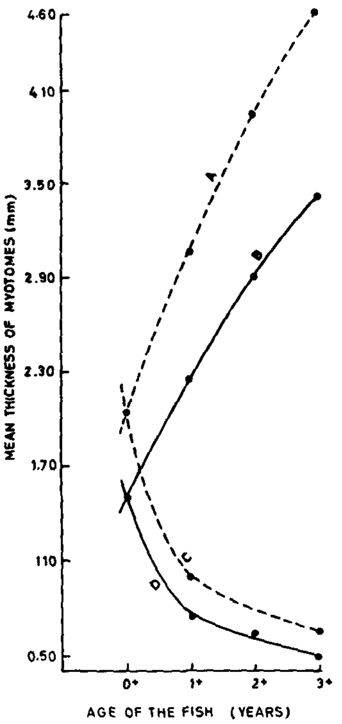
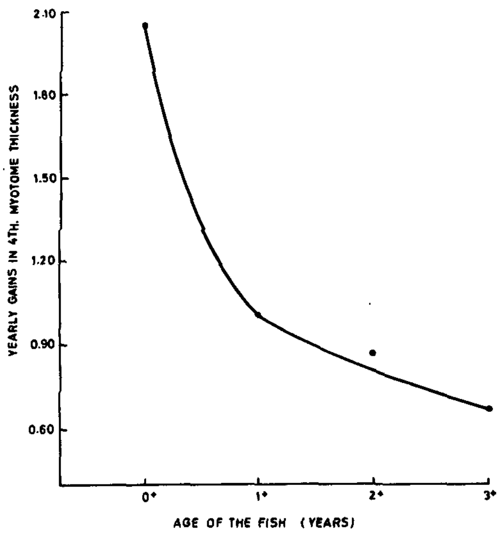

4.60
4.10
3.50
2.90
2.30
1.70
110
0.50
MEAN THICKNESS OF MYOTONES (mm)
A
B
C
D
0+
1+
2+
3+
AGE OF THE FISH (YEARS)

Fig. 12 Yearly gains in the thickness of 4th myotome of *O. punctatus*.


2.10
1.80
1.50
1.20
0.90
0.60
YEARLY GAINS IN 4TH. MYOTOME THICKNESS
0+
1+
2+
3+
AGE OF THE FISH (YEARS)

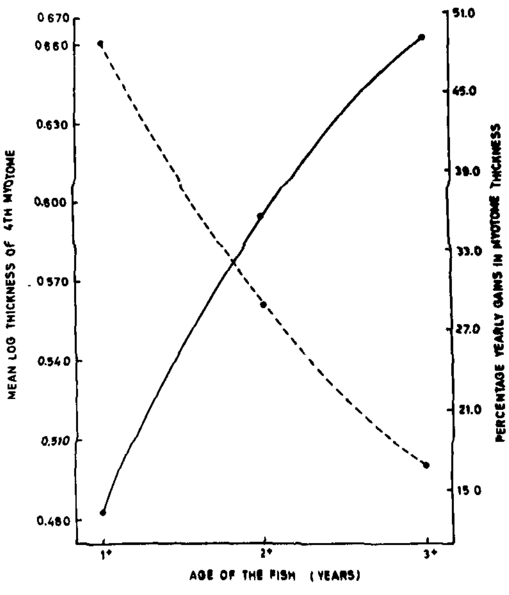
The present study conducted on various year-classes of *O. punctatus* revealed that different life periods of the fish were characterized by different characters of myotomic growth, i.e., the growth of the myotomes was age-specific, being rapid during the first year of life, and declining thereafter. Strikingly enough, the growth in the body length of this species was also recorded to be rapid during the first year of life but slowed down progressively during the subsequent years (Fig. 9).

The absolute growth of the myotomes, plotted as the regression of myotome thickness of age, indicated an increasing slope in the beginning, followed by a decreasing slope (Fig. 9).

The myotomes were found continually increasing in thickness as a result of absolute growth, but the rate of growth declined considerably with the age of the fish. The growth rate in the fishes of 0^+ to 3^+ year-classes was found to decline from 2.04 mm per year to 0.66 mm per year, for the 4th myotome. For the 21st myotome, on the other hand, it declined from 1.50 mm per year to 0.50 mm per year. This decline in the growth rates of the myotomes with increasing age of the fish was also evident when yearly gains plotted against time gave declining curves (Fig. 10).

The relative growth of the myotome when plotted as the logarithms of myotome thickness against time produced a curve which was found to rise steeply in the beginning, and thereafter the slope declined progressively. When the percentage yearly gains were plotted against time,

Fig. 11 Relative growth of 4th myotome of O. punctatus.


0.670
0.660
0.630
0.600
0.570
0.540
0.510
0.480
MEAN LOG THICKNESS OF 4TH MYOTOME
51.0
45.0
39.0
33.0
27.0
21.0
15.0
PERCENTAGE YEARLY GAINS IN MYOTOME THICKNESS
1+
2+
3+
AGE OF THE FISH (YEARS)

however, a continuous decline in the relative growth curve became obvious (Fig. 11). The percentage yearly gains at each age and the mean thickness of the myotome in O. punctatus of each year-class have been shown in Table XII. It was interesting to note that the decline in the relative growth was a regular and orderly process.

The observations thus indicate that the decline in the absolute and relative growth of the myotomes in O. punctatus was the function of increasing age.

It may be mentioned that the disparity observed between the absolute and the relative growth of the myotomes was more marked during the younger ages than during the older ones, as in the older year-classes the growth of the myotomes was slower and the differences in the growth were comparatively little both from the absolute and the relative view-point.

Another interesting finding that has emerged from the present studies was that each myotome maintained its own rate of growth. In O. punctatus, for example, the growth rate of the 4th myotome was found to be comparatively faster than that of the 21st myotome (Fig. 12). The ratios of these differential growth rates of the two myotomes, however, varied within a very restricted range. For the fishes of 0^+, 1^+, 2^+ and 3^+ year-classes, these ratios were found to be 1.360, 1.351, 1.353 and 1.320, respectively. The analysis of the intraspecific variations in these ratios gave a standard deviation of 0.0177 and a standard error (mean) of 0.1219. The variance and the coefficient of variation being 0.0003 and 1.3187, respectively.

The standard error of difference and the coefficient of difference in the thickness of 4th and 21st myotomes, in the fishes of the year-classes investigated, varied from 0.0250 to 0.0557 and 2.8272 to 17.0000, respectively. The variance ratio ranged from 0.1028 to 5.2167.

SUMMARY

The growth of the myotomes of O. punctatus, a common pond murrel, was found to be in direct correlation with that of the body. The growth of the myotomes seemed age-specific.

The myotomes were found to increase in thickness with the growth in the length of the fish but the rate of their growth declined markedly with age. The decline in the relative growth of the myotome was a regular process.

The growth rate of the 4th myotome was observed to be faster than that of the 21st myotome. The ratios of the differential growth rates of the two myotomes varied from 1.32 to 1.36.

CHAPTER - IV

THE MYOTOME THICKNESS-BODY LENGTH RELATIONSHIP IN THE FRESHWATER MURREL, *OPHICEPHALUS STRIATUS* BLOCH.

INTRODUCTION

With a view to assess the interspecific differences in the myotome thickness-body length relationship, established earlier in *Ophicephalus punctatus* (Chapter II), and to confirm the validity of the logarithmic relationship, a similar investigation was carried out on a closely related species, *Ophicephalus striatus* Bloch.

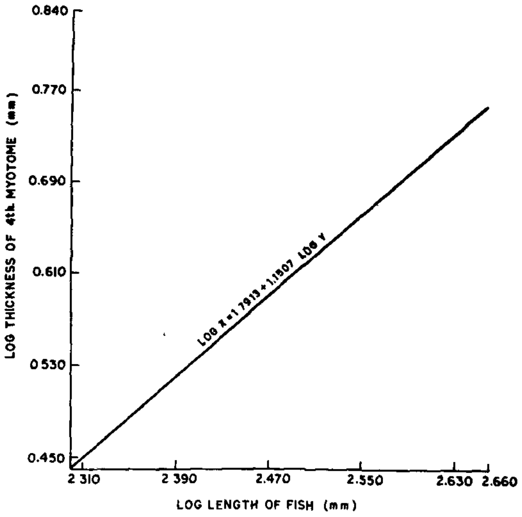
MATERIALS AND METHODS

Fishes of the size-range 209-451 mm were selected for these investigations. The methods used for the measurements of the thickness of the myotomes and for the statistical evaluation of the data were the same as described under 'Procedure and Methodology' (Pages 5-7).

RESULTS AND DISCUSSION

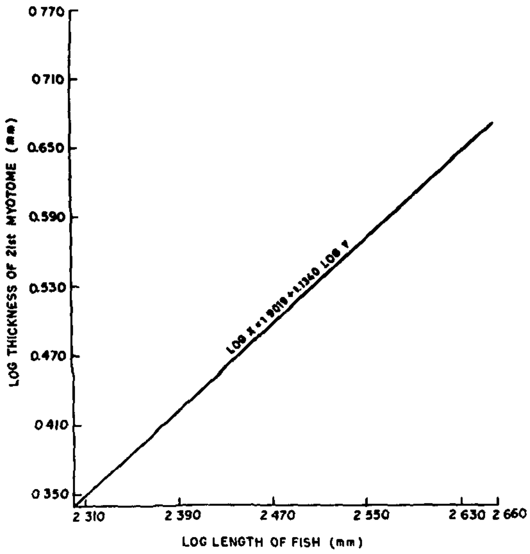
As in *O. punctatus*, in the present fish species as well, increase in the logarithms of the thickness of the myotomes was found to maintain

Fig. 13 Relationship between the thickness of 4th myotome and body length of *O. striatus*.



0.840
0.770
0.690
0.610
0 530
0.450
LOG THICKNESS OF 4th MYOTOME (mm)
LOG X =1 7913 + 1.1507 LOG Y
2 310
2 390
2.470
2.550
2.630
2.660
LOG LENGTH OF FISH (mm)

Fig. 14 Relationship between the thickness of 21st myotome and body length of _O. striatus_.


0 770
0 710
0.650
0.590
0.530
0.470
0 410
0 350
LOG THICKNESS OF 21st MYOTOME (mm)
2 310
2 390
2 470
2 550
2 630
2 660
LOG LENGTH OF FISH (mm)

a linear relationship with the increase in the logarithms of the body length (Figs. 13 and 14).

This relationship between the thickness of the 4th myotome and the body length of the fish was expressed by the following regression equation:

$$\log x = 1.7913 + 1.1507 \log y$$

Where, x was the body length of the fish (mm), and y was the thickness of the 4th myotome (mm).

The myosomatic ratio (MSR_4) ranged from 0.012 to 0.013. The SEm and Cv were found to be 0.0001 and 1.5625, respectively.

The myosomatic index (MSI_4) ranged from 1.248 to 1.387, with SEm of 0.0371 and Cv of 4.0883.

The 21st myotome thickness-body length relationship was expressed by the following equation:

$$\log x = 1.9019 + 1.1340 \log y$$

Where, x was the body length of the fish (mm), and y was the thickness of the 21st myotome (mm).

The myosomatic ratio (MSR_{21}) ranged from 0.010 to 0.011. The SEm was 0.0002 and the Cv was 3.8095.

The myosomatic index (MSI_{21}) varied from 1.019 to 1.124, the SEm and the Cv being 0.0270 and 4.4497, respectively.

From the regression equations it was apparent that, on a comparative basis, the myotome thickness in relation to body length

O. punctatus striatus

was more in ~~O. striatus~~ than in O. ~~punctatus~~. This fact was further confirmed by making a comparison of the myosomatic ratios and indices in the two species, both of which were found to be higher for O. punctatus than for O. striatus. From these findings it becomes evident that the myotome thickness-body length relationship in fish is species specific.

SUMMARY

Straightline logarithmic relationships were found to exist between the thickness of each of the 4th and 21st myotomes and the body length of the freshwater murrel, O. striatus. For the 4th myotome thickness-body length relationship, the intercept 'a' of the regression was 1.7913 and the slope 'b' was 1.1507. For the 21st myotome thickness-body length relationship, however, the intercept was 1.9019 and the slope was 1.1340.

The myotome thickness-body length relationship in fish appeared to be species specific.

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TABLE I Sizes of epaxial and hypaxial portions and the distance traversed by lateral septum ~~for~~ from surface to sagittal axis in *O. punctatus*.

S.No.	Body length of fish (mm)	Size of epaxial portion (mm)			Size of hypaxial portion (mm)			Distance of lateral septum from surface to sagittal axis (mm)		
		Mean ± SE	Variance	Coefficient of variability	Mean ± SE	Variance	Coefficient of variability	Mean ± SE	Variance	Coefficient of variability
1	120	12.26 ± 0.039	0.0079	0.7259	18.00 ± 0.031	0.0049	0.3888	7.52 ± 0.037	0.0068	1.1037
2	170	19.40 ± 0.262	0.3457	3.0309	27.22 ± 0.329	0.5416	2.7038	10.96 ± 0.088	0.0388	1.7974
3	220	27.20 ± 0.314	0.4942	2.5845	36.44 ± 0.067	0.0228	0.4143	14.68 ± 0.037	0.0068	0.5653
4	248	29.00 ± 0.345	0.5944	2.6586	38.50 ± 0.322	0.5190	1.8727	17.50 ± 0.396	0.7849	5.0628

TABLE - II Coefficient of difference, standard error of difference and variance ratio of the lengths of epaxial and hypaxial portions in *O. punctatus*.

S.No.	Body-length of fish (mm)	Mean length of epaxial portion (mm)	Mean length of hypaxial portion (mm)	Coefficient of difference	Standard error of difference	Variance ratio
1	120	12.26	18.00	36.1006	0.0498	1.612
2	170	19.40	27.22	5.9063	0.4205	0.638
3	220	27.20	36.44	10.8196	0.3667	21.675
4	248	29.00	38.50	6.3672	0.4719	1.143

TABLE III Relationship between the body length of fish and length of epaxial portion in *O. punctatus*.

S.No.	Log body length of fish (mm)	Log length of epaxial portion (mm)	Regression constants	Correlation coefficient ± SE	Significance
1	2.0792	1.0934			
2	2.0792	1.0899			
3	2.0792	1.0864			
4	2.0792	1.0864			
5	2.0792	1.0864			
6	2.2304	1.2900			
7	2.2304	1.3010			
8	2.2304	1.2967			
9	2.2304	1.2672			
10	2.2304	1.2833	a = 1.1962	0.9936±0.0031	1% level
11	2.3424	1.4346	b = 0.8082		(P > 0.01)
12	2.3424	1.4232			
13	2.3424	1.4440			
14	2.3425	1.4232			
15	2.3425	1.4472			
16	2.3945	1.4624			
17	2.3945	1.4502			
18	2.3945	1.4771			
19	2.3945	1.4698			
20	2.3945	1.4518			

TABLE IV Relationship between the body length of fish and length of hypaxial portion in *O. punctatus*.

S.No.	Log body length of fish (mm)	Log length of hypaxial portion (mm)	Regression constants	Correlation coefficient ± SE	P (t-test)	Significance
1	2.0792	1.2577				
2	2.0792	1.2553				
3	2.0792	1.2553				
4	2.0792	1.2553				
5	2.0792	1.2529				
6	2.2304	1.4440				
7	2.2304	1.4502				
8	2.2304	1.4281				
9	2.2304	1.4232				
10	2.2304	1.4281	a = 0.9244 b = 0.9163	0.9939±0.0031	$>$0.01	1% level
11	2.3424	1.5623				
12	2.3424	1.5587				
13	2.3424	1.5623				
14	2.3424	1.5611				
15	2.3424	1.5635				
16	2.3945	1.5821				
17	2.3945	1.5775				
18	2.3945	1.5966				
19	2.3945	1.5798				
20	2.3945	1.5911				

TABLE - V Measurements of the 4th myotome in O. punctatus.

S.No.	Mean total body-length of fish (mm)	Age of the fish (years)	Mean thickness of 4th myotome (mm)	S.E.M.	Variance	Coefficient of variability	S.E.Sd.	S.E.Cv.
1	120	0^+	2.04	0.020	0.0028	2.5980	0.0141	0.6983
2	170	1^+	3.04	0.020	0.0028	1.7434	0.0141	0.4657
3	220	2^+	3.92	0.036	0.0090	2.4234	0.0253	0.6478
4	248	3^+	4.58	0.006	0.0002	0.3711	0.0045	0.0991

TABLE - VI   Measurements of the 21st myotome in *O. punctatus*.

S.No.	Mean total body-length of fish (mm)	Age of the fish (years)	Mean thickness of 21st myotome (mm)	S.E.M.	Variance	Coefficient of variability	S.E.Sd.	S.E.Cv.
1	120	0^+	1.50	0.052	0.0191	9.2266	0.0368	2.4852
2	170	1^+	2.24	0.015	0.0017	1.8571	0.0109	0.4963
3	220	2^+	2.89	0.015	0.0017	1.4394	0.0109	0.3845
4	248	3^+	3.39	0.020	0.0028	1.5634	0.0141	0.4176

TABLE - VII Coefficient of difference, standard error of difference and variance ratio of 4th and 21st myotome thickness in *O. punctatus.*

S.No.	Total body length of fish (mm)	Mean thickness of myotomes (mm)		Coefficient of difference	Standard error of difference	Variance ratio
		4th myotome	21st mytome			
1	120	2.04	1.50	2.8272	0.0557	0.1466
2	170	3.04	2.24	0.5106	0.0250	1.6236
3	220	3.92	2.89	7.5735	0.0390	5.2167
4	248	4.58	3.39	17.0000	0.0260	0.1028

TABLE VIII Relationship between the body length of the fish and the thickness of 4th myotome in *O. punctatus*.

S.No.	Log body length of fish (mm)	Log thickness of 4th myotome (mm)	Regression constants	Correlation Coefficient ± SE	Significance
1	2.0792	0.3010			
2	2.0792	0.3010			
3	2.0792	0.3222			
4	2.0792	0.3010			
5	2.0792	0.3222			
6	2.0792	0.3222			
7	2.0792	0.3010			
8	2.2304	0.4771			
9	2.2304	0.4914			
10	2.2304	0.4914			
11	2.2304	0.4624			
12	2.2304	0.4914			
13	2.2304	0.4771			
14	2.2304	0.4914	a = 1.7964 b = 0.9083	0.9972±0.0011	1% level (P > 0.01)
15	2.3424	0.6021			
16	2.3424	0.6021			
17	2.3424	0.5798			
18	2.3424	0.6021			
19	2.3424	0.5798			
20	2.3424	0.5911			
21	2.3424	0.6021			
22	2.3945	0.6609			
23	2.3945	0.6590			
24	2.3945	0.6628			
25	2.3945	0.6609			
26	2.3945	0.6599			
27	2.3945	0.6637			
28	2.3945	0.6609			

TABLE IX Relationship between the body length of the fish and the thickness of 21st myotome in *O. punctatus.*

S.No.	Log body length of fish (mm)	Log thickness of 21st myotome (mm)	Regression constants	Correlation coefficient ± SE	Significance
1	2.0792	0.1761			
2	2.0792	0.1139			
3	2.0792	0.2304			
4	2.0792	0.1301			
5	2.0792	0.2041			
6	2.0792	0.1903			
7	2.0792	0.1761			
8	2.2304	0.3502			
9	2.2304	0.3617			
10	2.2304	0.3579			
11	2.2304	0.3385			
12	2.2304	0.3502			
13	2.2304	0.3424	'a' (Intercept)		
14	2.2304	0.3502	= 1.9281	0.9887±0.0045	1% level (P > 0.01)
15	2.3424	0.4609	'b' (Slope)		
16	2.3424	0.4669	= 0.8802		
17	2.3424	0.4548			
18	2.3424	0.4698			
19	2.3424	0.4518			
20	2.3424	0.4609			
21	2.3424	0.4609			
22	2.3945	0.5185			
23	2.3945	0.5250			
24	2.3945	0.5353			
25	2.3945	0.5302			
26	2.3945	0.5289			
27	2.3945	0.5416			
28	2.3945	0.5315			

TABLE X Myosomatic ratios and indices (4th myotome) in *O. punctatus*.

S.No.	Total body length of fish (mm)	Age of the fish (mm)	Mean thickness of 4th myotome	Myosomatic ratio	Mean ± SE	Variance	Coefficient of variability	Myosomatic index	Mean ± SE	Variance	Coefficient of variability
1	120	0^{+}	2.04	0.017				1.700			
2	170	1^{+}	3.04	0.017	0.0177 ± 0.00035	0.0000004	3.948	1.788	1.778 ± 0.0300	0.0036	3.374
3	220	2^{+}	3.92	0.017				1.781			
4	248	3^{+}	4.58	0.018				1.846			

TABLE XI Myosomatic ratios and indices (21st myotome) in *O. punctatus*.

S.No.	Total body length of fish (mm)	Age of the fish (mm)	Mean thickness of 21st myotome	Myosomatic ratio	Mean $\pm$ SE	Variance	Coefficient of variability	Myosomatic index	Mean $\pm$ SE	Variance	Coefficient of variability
1	120	0^{+}	1.50	0.0125				1.250			
2	170	1^{+}	2.24	0.0131	0.0130 $\pm$ 0.00025	0.0000002	3.8461	1.317	1.311 $\pm$ 0.0232	0.00211	3.5469
3	220	2^{+}	2.89	0.0131				1.313			
4	248	3^{+}	3.39	0.0136				1.366			

TABLE XII Growth of the myotomes in *O. punctatus*.

S.No.	Mean length of fish (mm)	Age of the fish (years)	Mean thickness of myotomes (mm)		Growth rates of myotomes (per year)		Ratio of the rates of growth			Mean relative growth of 4th myotome in successive years
			4th myotome	21st myotome	4th myotome	21st myotome	mean ± SE	Variance	Coefficient of variability	
1	120	0^+	2.04	1.50	2.04	1.50				-
2	170	1^+	3.04	2.24	1.00	0.74	1.346 ± 0.012	0.00031	1.3187	49.01
3	220	2^+	3.92	2.89	0.88	0.65				28.94
4	248	3^+	4.58	3.39	0.66	0.50				16.83